Micro-X-Ray Absorption Near Edge Structure: The Application to the Study of Rock Weathering: Observation of Lichen-induced Oxidation of Fe in Hawaiian Basalt

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INTRODUCTION

Lichens, along with other microorganisms, are known to contribute significantly to the weathering or degradation of rocks and minerals[1]. One such manifestation is the deterioration of buildings etc. It is known that Lichens produce substances that can assist in the chemical breakdown of minerals, such as organic acids etc., though knowledge of the precise mechanisms involved is lacking. We have carried out the preliminary experiments using the micro X-Ray Absorption facility under development at the ALS to study this weathering phenomenon.

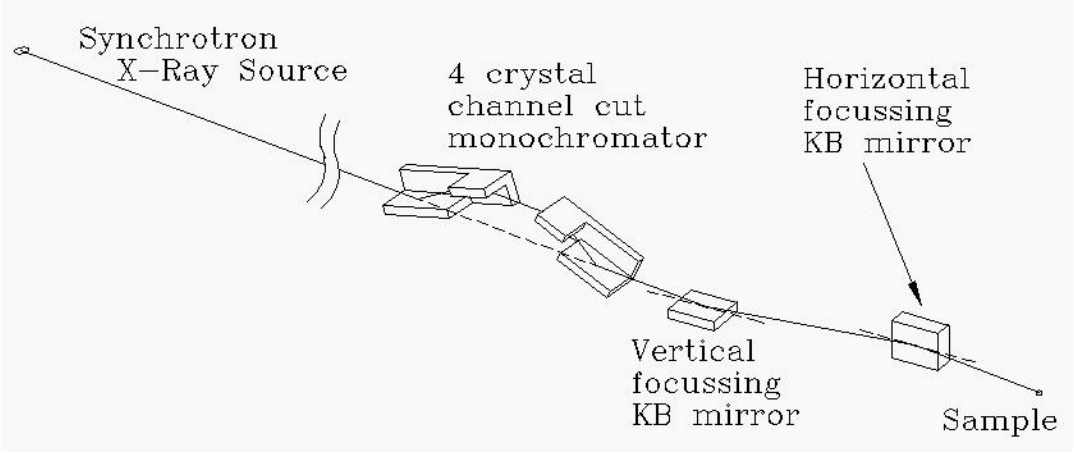

Figure 1. Schematic layout of the K-B mirrors and four crystal channel-cut monochromator.

EXPERIMENTAL

The schematic of the experimental setup is shown in Fig.1. It consists of a Si(111) four crystal monochromator in the (+--+) crystal configuration followed by a Kirkpatrick Baez grazing incidence mirror pair to focus the bending magnet source down to a spot size of around 1 micron (1). The 4 crystal monochromator naturally produces a fixed exit monochromatic beam position which allows the monochromator to be energy scanned whilst maintaining positional stability on the sample to better than 0.5 micron. The sample is mounted on a XY scanning stage and the fluorescent x-rays are detected by a solid state detector.

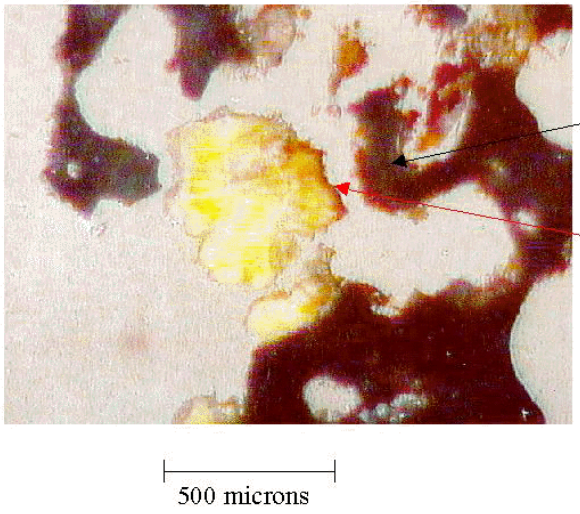

Figure 2. Optical micrograph

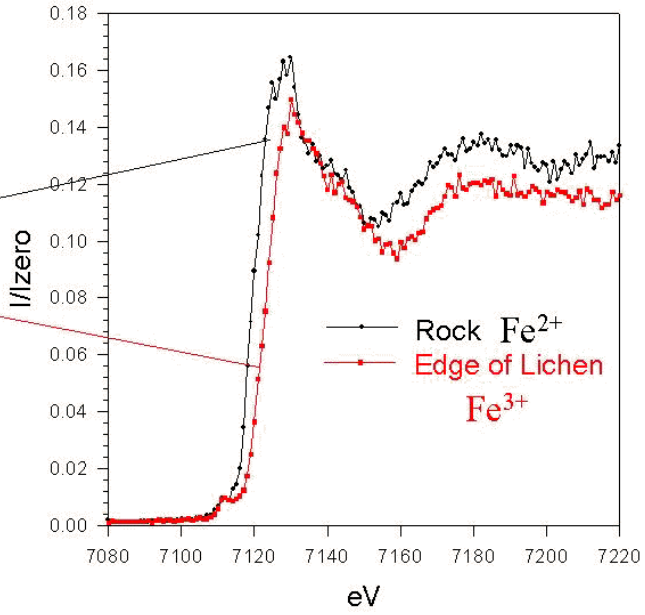

Figure 3. Fe K Near Edge X-ray Fluorecence Spectra

The optical micrograph of fig. 2 shows part of a thin section of basalt rock (dark areas) and part of a resident lichen (white/yellow area in the center). The XAS measurements of fig.3 were made by placing the monochromatic beam (1-2 microns in size) at the points of interest (on the surface of the lichen and in the body of the rock, respectively) then scanning through the characteristic K absorption edge for iron. The absorption edge shift is indicative of the oxidation state change from Fe^{2+} (in the rock) to Fe^{3+} (on the lichen).
The observation demonstrates that the lichen biochemically facilitates this oxidation state change by production of some breakdown compound (eg. organic acid) in order to absorb nutrients to sustain itself. In doing so, it contributes to the overall weathering process.

This demonstration experiment illustrates the importance of this capability to determine oxidation states with spatial resolution on the micron scale. In addition, though this particular sample had been sectioned, it is possible to envisage that the μXAFS tool could be applied to observe microorganism behavior with minimum alteration to the natural setting.

REFERENCES

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